Distributed Energy Resources for Carbon Emissions Mitigation

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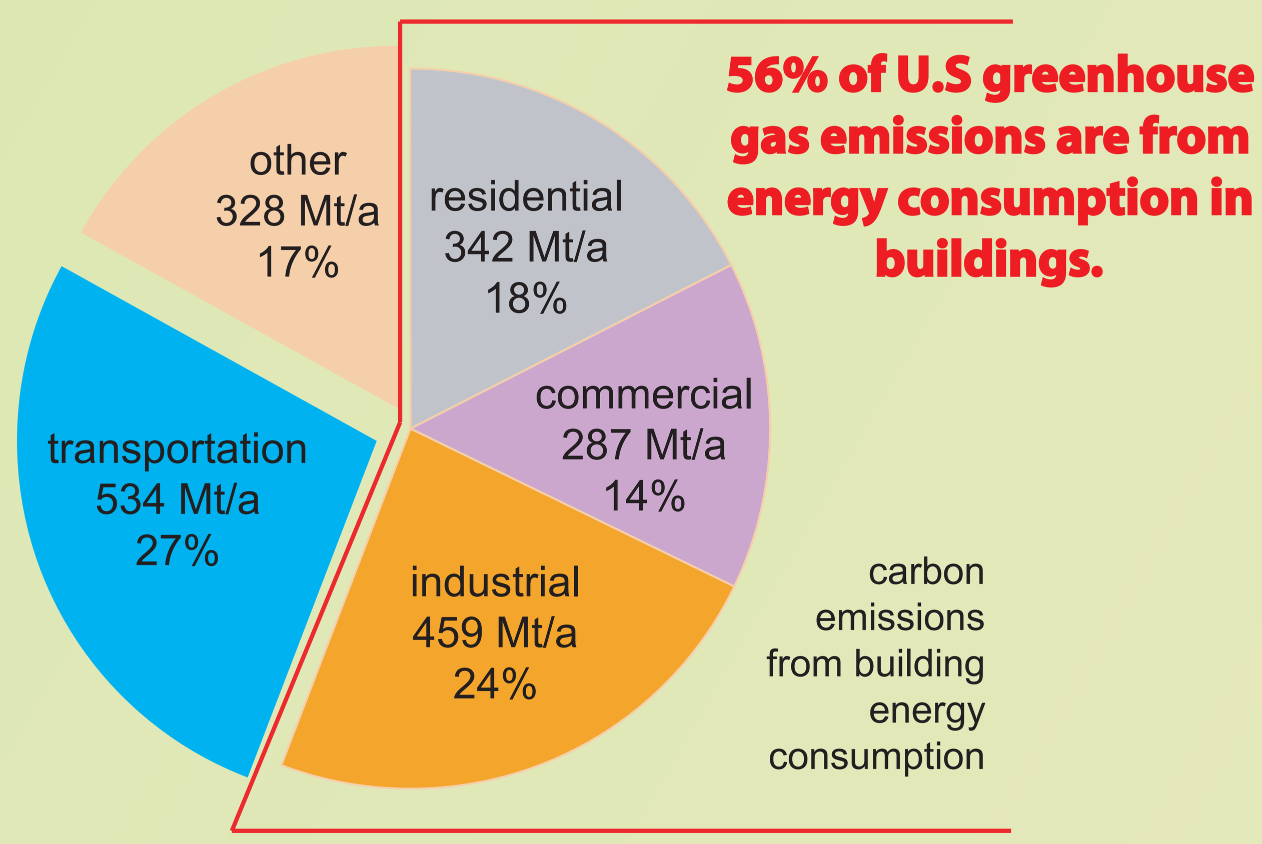
Introduction

U.S. Greenhouse Gas Footprint Footprint

2005 United States Greenhouse Gas Emissions By Sector
(Mt/a carbon equivalent)



source: Energy Information Administration, 2006. *Emissions of Greenhouse Gases in the United States 2005.* DOE/EIA-0573 (2005)

Distributed Energy Resources For Improved Carbon Efficiency

Distributed Energy Resources (DER) are a range of energy conversion and storage technologies including small-scale power generation, thermal and electrical storage, and thermally activated cooling. These technologies can reduce the carbon-intensity of meeting end-use energy loads. Technologies include:

Combined heat and power (CHP): on-site electricity generation (natural gas engines or fuel cells) with waste heat recovery for site heating needs. 60-85% of primary fuel energy can be utilized.

Thermally activated cooling: Absorption and adsorption chillers use heat, rather than electricity, to provide cooling.

Solar technologies: Photovoltaics provide renewable electricity. Solar thermal collectors can be used to provide heat for domestic hot water and/or thermally activated cooling. High temperature collectors can provide steam for industrial processes.

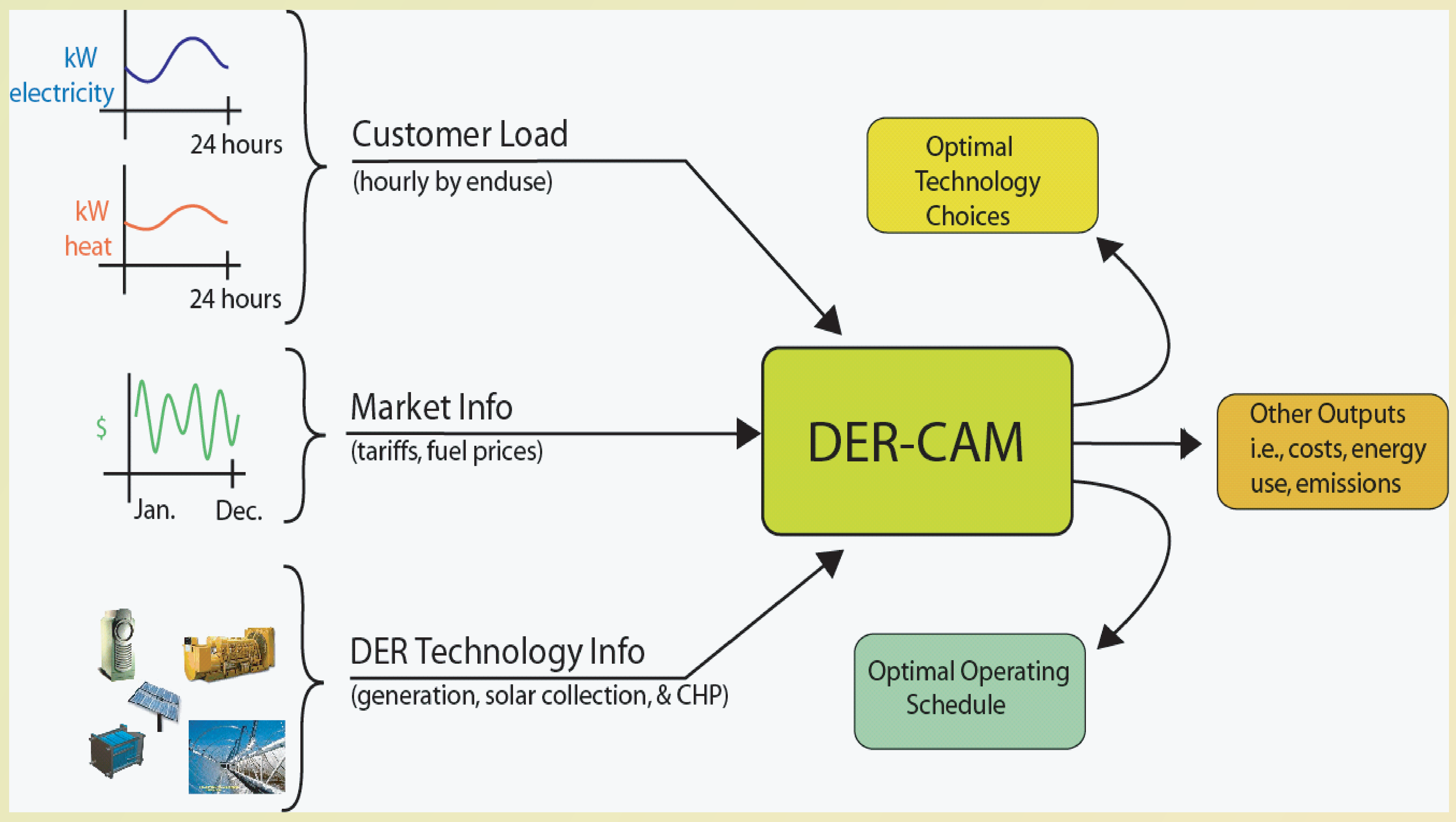
Storage: Storage devices such as batteries and thermal tanks can be used to improve reliability and to apply energy produced or purchased during a low value time to loads at a higher value time.

The Distributed Energy Resources Customer Adoption Model

The Distributed Energy Resources Customer Adoption Model (DER-CAM) is a site-specific, fully technology neutral DER investment and operation optimization tool developed by the DER team at the Berkeley Lab.

Inputs include
- site hourly electricity and heating load profiles
- energy prices
- DER investment options
- operational constraints such as limits on carbon emissions

Outputs include
- optimal DER investment
- optimal operating schedule
- performance measures such as annual energy cost, electricity and natural gas consumption, and carbon emissions attributed to energy consumption



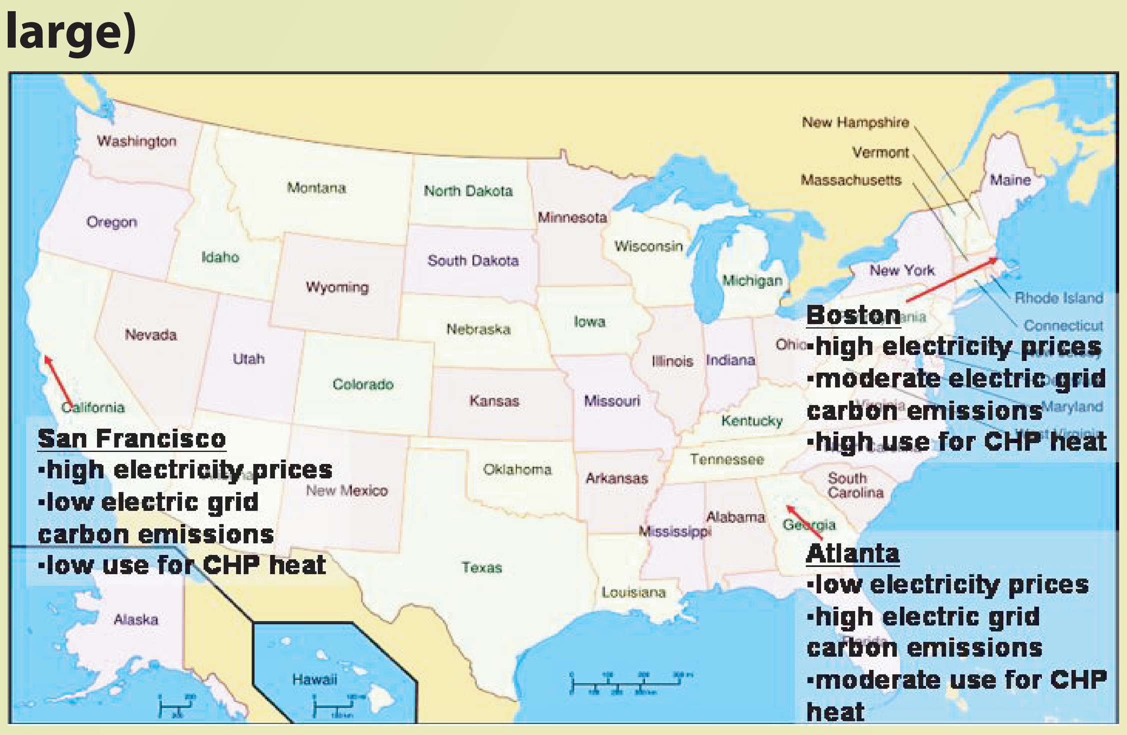
Experiment: What are the economically optimal DER technologies for U.S commercial buildings *under a carbon tax*?

DER-CAM was used to determine the economically optimal DER investment for prototypical commercial buildings in several U.S. cities under a range of carbon tax levels.

Building energy simulations were conducted to determine electricity, natural gas, space and water heating, and cooling loads for each building type in each location. City-specific weather, energy costs, and electric grid carbon-intensity values were used.

Building Types:
- **health care (small and large)**
- **lodging (small and large)**
- **office (small and large)**

Cities:
- **Atlanta, Georgia**
- **Boston, Massachusetts**
- **San Francisco, California**



Results: Technology Adoption, Costs, and Carbon Emissions

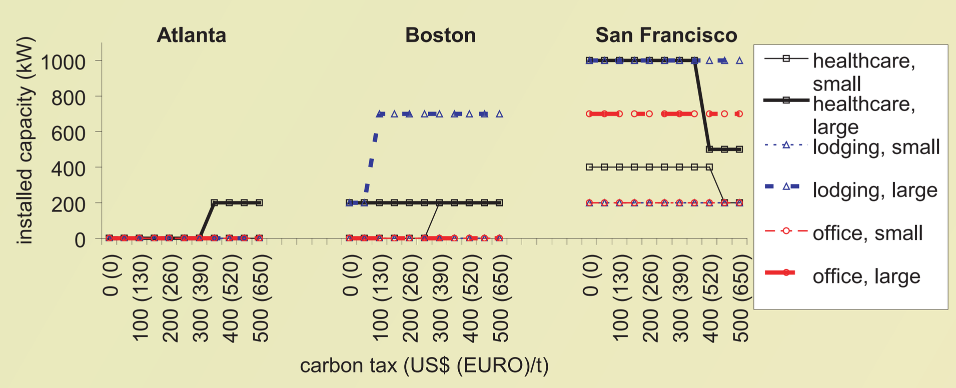


Figure 1: installed capacity of CHP generators

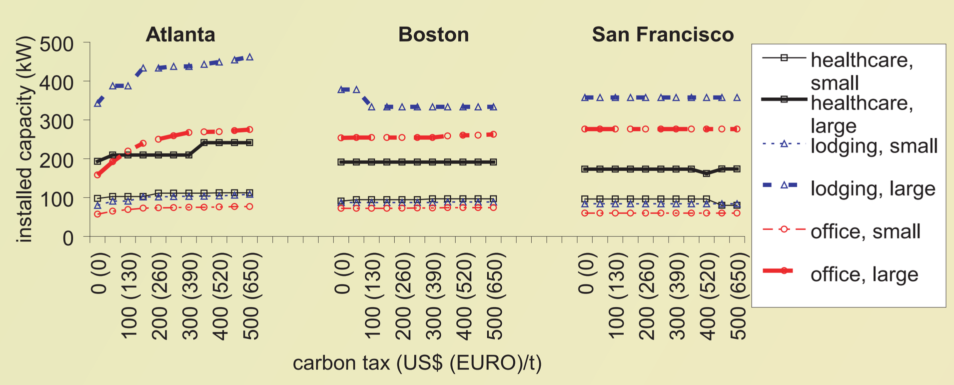


Figure 2: installed capacity of absorption chillers

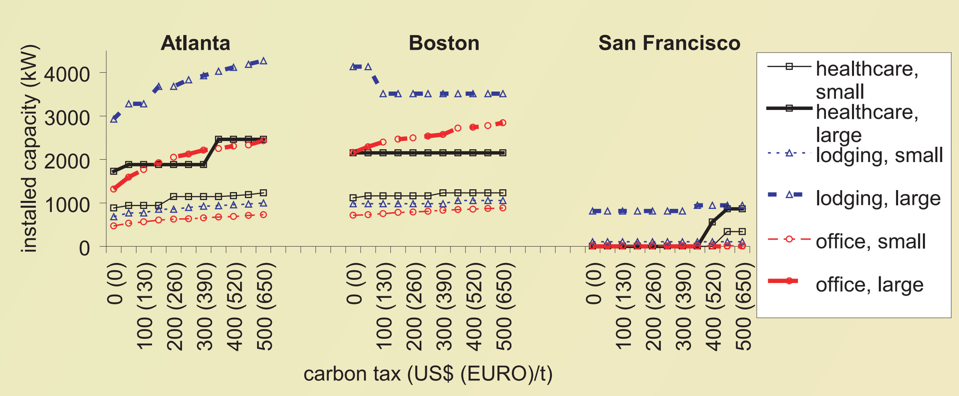


Figure 3: installed capacity of solar therm collectors

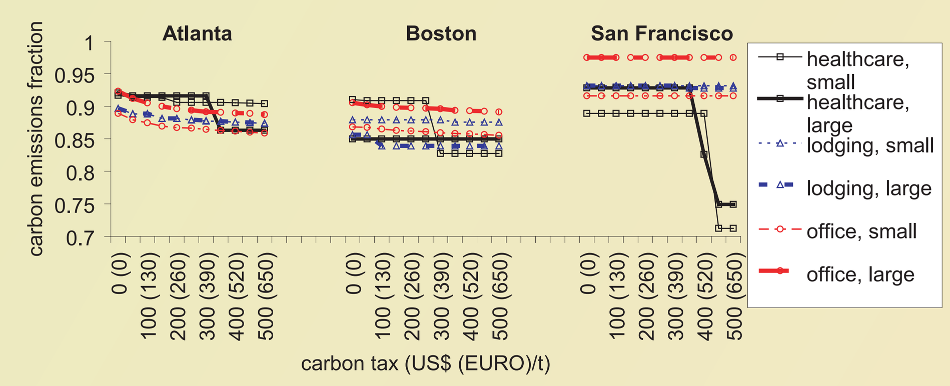


Figure 4: site-attributable carbon emissions as a fraction of no-invest carbon emissions

note: . Thermal storage was never purchased. Electrical storage and photovoltaics were only purchased in a handful of cases.

Conclusions

Atlanta
- Electricity prices are too low to incent CHP.
- Integrated solar thermal/absorption chiller systems are economic even without a carbon tax.
- Solar collector/absorption chiller system size increases with carbon tax.
- A realistic carbon tax of $100/tC incents less than one percent carbon reductions.

Boston
- CHP is marginally economic without the carbon tax and is increasingly adopted with carbon tax.
- Solar thermal/absorption chiller systems are economic.
- A realistic carbon tax level ($100/tC) incents less than one percent carbon reduction.

San Francisco
- All buildings considered would benefit financially from CHP, even without carbon taxes.
- Carbon emissions reductions from DER investment are less than in Atlanta and Boston.
- The relatively low electric grid marginal carbon emissions and high electricity prices in California induce some carbon-inefficient behavior, such as operating CHP when the heat is not needed.
- Carbon taxes have little effect on investment behavior and almost none on carbon emissions.

Overall

A realistic carbon tax ($100/tC) is too small to incent significant carbon-reducing effects on economically optimal DER adoption.

- Cost reduction and carbon reduction objectives are roughly aligned, even in the absence of a carbon tax.
- A carbon tax greater than $500/tC would be required to incent significant adoption of carbon-free renewable energy.

Acknowledgments: The work described in this report was funded by the Office of Electricity Delivery and Energy Reliability, Distribution System Integration Program of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231, and by the California Energy Commission, Public Interest Energy Research Program, under Work for Others Contract No. 500-03-024. The poster also builds on prior work the authors have completed together with Giri Venkataramanan, University of Wisconsin, Madison, Afzal S Siddiqui, University College, London, Michael Stadler, Center for Energy and innovative Technologies, Ypsertal, Austria, Bala Chandran, Kristina Hamachi LaCommare, Judy Lai, and Nan Zhou, Berkeley Lab, and Owen Bailey, Cornell University.